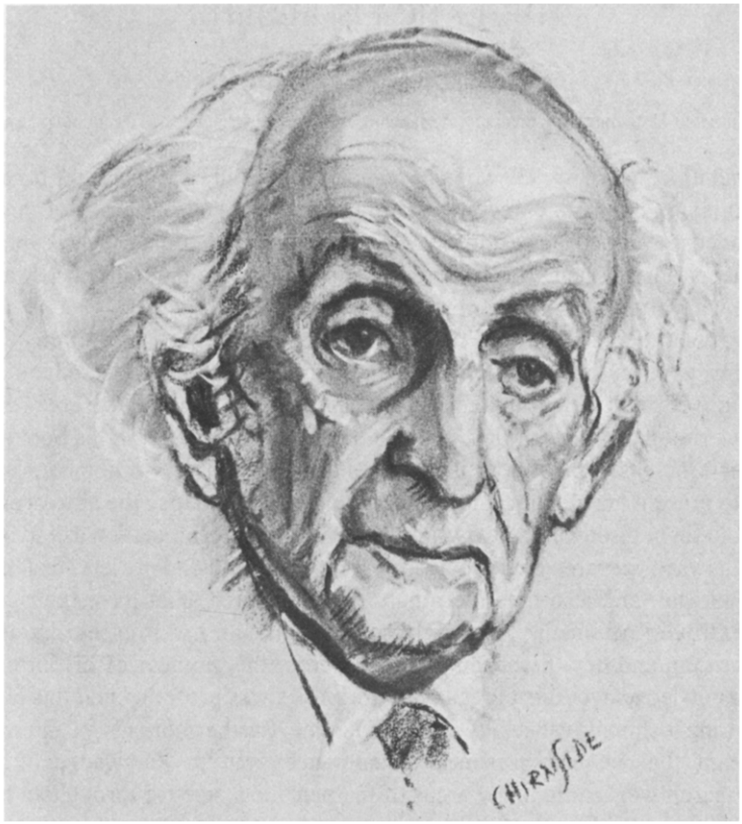
Comp. & Maths. with Appls. Vol. 1, pp. 257–268. Pergamon Press, 1975. Printed in Great Britain.

IN MEMORY OF CORNELIUS LÁNCZOS

ERVIN Y. RODIN
Department of Systems Science and Mathematics, Washington University, U.S.A.

(*Received December* 1975)

The present issue of Computers and Mathematics with Applications is a double one. It is special also, because the papers were all written to the memory of one who had at least as much to do with weaving the connections between computers and mathematics, as any other single person.



When this Journal was founded, Lánczos was one of the people we approached and invited him to join our Editorial Board. His response was characteristically humble: ".... I feel that it would not be fair to the younger generation if the old 'war horses' would sit in judgement of their present trends and efforts." He declined our invitation. However, he did agree to contribute a paper on the analysis of random sequences. In fact, on June 7, 1974, he wrote:

"The co-operation with the Computer Section of the Central Physical Research Institute, Budapest, worked out quite well. I thought you might be interested in the preliminary results.

First we investigated a random sequence generated by the Computer by one of the standard procedures. We expected that the phase angle θ_k will be practically evenly distributed over the entire circle; (we operated with 128 and even 256 ordinates). The peculiar result was that certain 'bald patches' remained along the circle, indicating that the random sequence was not properly random from the standpoint of the Fourier analysis. My next idea was that we could generate 'ideal random noise' with the help of the Fourier analysis. For this purpose we distributed the phase angles *evenly* over the whole circle, allowing for the identification index k a Monte Carlo sequence. The amplitude of all the Fourier components was chosen as 1, thus obtaining an 'ideal white noise'.

We then proceeded to the construction of an 'ideal random noise'. Here again the phase angles were evenly distributed, in addition the amplitudes were also evenly distributed, whereas the identification index k was in both cases (and independently) chosen as a Monte Carlo sequence. I think that the results will be quite interesting; (I avoid the word 'extremely', much loved by many numerical analysts).

In about a week's time I go to Hungary and will stay there for about three weeks. During this time I hope that we will come to quite definite results, which may be publishable."

It was during the three weeks of his visit, mentioned in his letter, that Lánczos passed away.

In this special issue we decided to pay a Rashomon-type, many faceted tribute to this unusual man. In addition to all the diverse papers which were written in his memory, there is a posthumous one by Lánczos himself—actually completed and written up by his co-worker, B. Gellai. And then, in this section, we are giving facets of, facts about, and feelings concerning Cornelius Lánczos. The six contributions in this Memorial were written by colleagues, old and young; collaborators and students; Hungarians and Irish and other, men and women. None of these contributions was "edited"; for we felt that in order to obtain a complete picture of the man that Lánczos was, we need the repetitions implied by the multifaceted presentation, which we arranged in alphabetical order. None of these contains a full bibliography; however, the references by R. Butler directs the reader to that.

THE LÁNCZOS LEGEND

R. BUTLER
Department of Mathematics, University of Manchester Institute of Science and Technology, England

I first met Cornelius Lánczos in 1959 when he came from Dublin to Manchester for a week to give a series of lectures on his work on economisation of series. I had not heard of this work at that time and attended the first lecture more or less as a duty. At once I was captivated by the approach to presenting mathematics. Here was something of remarkable value, and, as I soon found, it went with a most charming personality.

By good fortune the journey from Professor Lánczos's home to our Institute was both quick and easy and this gave us the opportunity to invite him very often to give individual lectures or courses. He enjoyed both being invited and staying with us. One of the courses was of four evening lectures on Space through the Ages (later to be incorporated in his book of that name) and the audience increased nightly until by the end it had doubled in number. He had a quite unique ability to present mathematical ideas according to the audience (he always enquired of the level) and to hold them throughout, always avoiding algebraic manipulation as far as possible. He told me that he always prepared every lecture in great detail and had preserved all his notes. This was essential he said, and also he added that a good lecturer must have the right mixture of introvert and extrovert personality. Certainly he had both, and it was especially noticeable how he enjoyed lecturing and how he became an actor from the moment of his introduction to an audience. His knowledge over most areas of mathematics was profound and this played no small role in his lecturing technique especially at question time. Furthermore his exceptionally long and active life meant that he had personal acquaintance with or knowledge of many of the outstanding research workers in many areas of mathematical science throughout a large part of this century. This enabled him to add those personal touches in his lectures that so enchant an audience. He had a firm belief in going back to the original paper on a topic whenever possible and his proficiency with languages enabled him to do this with ease.

Professor Lánczos wrote eight books and, as in his lectures, he aimed to avoid formal mathematics whenever he could. This gives his books a wider appeal than would otherwise have been possible, though it must be admitted that to fill in the analysis is often a major task! At our last meeting I asked him what above all he would like to be remembered for in later years. His answer was clear and surprising, "For having introduced a new style of text book", whereas one might have expected him to have chosen some topic from his work in the application of Chebyshev polynomials, Fourier series, analysis and synthesis, Fourier transforms, matrix eigenvalues and eigen functions, the Gamma function; ill-posed problems and in mathematical physics his many papers on relativity theory, quantum mechanics, electromagnetism and classical mechanics. In all he wrote 100 papers. In 1960 he was awarded the Chauvenet prize of the American Mathematical Society for a paper on the decomposition of an arbitrary rectangular matrix, which has recently found important application in control theory. He received honorary awards from the Royal Irish Academy, Dublin (1958), Trinity College, Dublin (1962), National University of Ireland (1970), University of Frankfurt am Main (1972), University of Lancaster (1972). On the occasion of his 80th birthday he was presented with a Festschrift entitled "Studies in Numerical Analysis".

In early 1972 I got the Director of the University of Manchester Audio Visual Service to agree to make telerecordings of Professor Lánczos, an idea I had fostered for some time. After correspondence it was decided to organize a six lecture course entitled "The Life and Work of Albert Einstein: Cosmic World Order" to take place in October. The first two lectures are on video tape, the remaining four are on audio tape. Three other telerecordings were made: two group discussions and a personal recording entitled "Autobiographical Discourse". This latter is quite remarkable in that alone with a cameraman he spoke extempore and with perfect fluency for 55 mins about his life from his early childhood and his career. Here we learn that one of his principles was always to say "Yes" to any offered opportunity, with the result that during his career he held twelve different positions and seven visiting professorships. With regard to the offer of a Senior Professorship at the Institute of Advanced Studies, Dublin in 1953 he said "I was already 60 years old. In the States I would have to resign in about five years. So this offer came to me like a real salvation because at our Institute in Dublin one can work up to 75 which is unusual, so I still had fifteen years of active academic life". In fact he had twenty-one years for, as he said to me, "Retirement merely means one carries on, on half pay". In the year of his death, 1974, he published his last book "The Einstein Decade, 1905–1915" which, though based on the recorded lectures, followed his rereading all the original papers. He wrote at Easter 1974 to apologise for a lapse of two months in his correspondence; he had been too engrossed in these Einstein papers to do anything else. He had great powers of concentration and was a true individual researcher. Rarely did he have contact with undergraduates except as a special lecturer.

Cornelius Lánczos was born on February 2nd 1983 in Szekesfehervar, Hungary and died in Budapest on June 24th 1974. Whilst his name is curiously attached to only a few of the results, theorems and discoveries he made, his influence on many areas of mathematics and its presentation will be increasingly recognised. He had the extreme humility that is a characteristic of the truly great and disliked arrogance in anyone. He treated all persons, great or small, with the same courtesy and consideration, and disliked preferential treatment. I remember his refusing to visit the Jodrell Bank telescope other than as an ordinary visitor. He worked because he loved to work, and not because he sought fame. The Dublin Institute suited him perfectly in every way. In his autobiography he says "Ireland with its old world atmosphere appealed to me tremendously and the Institute is organised along exceedingly pleasant lines". He was concerned that his physical health would give out before his mental powers had been exhausted but I believe his final publications in 1974 in the field of relativity were his goal in that area which was his first love, and he can thus have had no regrets.

I recall a conversation we once had in which mathematicians and musicians were paired off and it led me to ask with whom he would like to be identified. "Schubert" was his immediate answer "for he had breadth, depth and romance". Certainly Lánczos was romantic, and indeed on the one occasion I heard him play the piano he chose a well-known Schubert impromptu. Mrs. Lánczos told me he had ensembles at their home quite often. She also said he should never have any regrets at all, for he had led an eminently successful life as a mathematician and had he chosen otherwise he could have done the same in music.

The Manchester recordings together with all his writings complete what we now call the Lánczos Legend and it was accomplished in his lifetime. He was very proud and pleased to have been recorded. For myself I can merely say how privileged I have been to have known Professor Lánczos as man and mathematician for some fifteen years.

BIBLIOGRAPHY

1. Cornelius Lánczos, Mathematician and Mathematical Physicist by R. Butler and H. G. Hopkins, Advance, Vol. 15, October 1974, p. 53. (This contains full details of the nine hours of video and audio recordings. Brief details are,

Video tape recordings
(i) Autobiographical Discourse. His education, life and career.
(ii) Discussion Interview: "Professor Lánczos's Contributions to Mathematics;;.
(iii) Discussion Interview: "Albert Einstein: the Man and Relativity".
(iv) Lectures I and II of "The Life and Work of Albert Einstein: Cosmic World Order".

Audio tape recordings
(v) Lectures III and VI as above. Available from the University of Manchester Audio Visual Service.)
2. Obituary Notice, "The Times", 9th July 1974, R. Butler and H. G. Hopkins.
3. Festschrift: Studies in Numerical Analysis (Academic Press, 1973).

ON CORNELIUS LÁNCZOS

A. ERDÉLYI
Mathematics Institute, University of Edinburgh

I first met Lánczos about 1950, and we became personal friends even though mathematically we had very little in common, had few mathematical conversations, and never lived close enough to meet frequently. But, without being practising orthodox Jews, we both liked Jewish traditions, and shared musical interests.

One of my vivid recollections is Kornél visiting me in Pasadena. He then lived at the far end of Los Angeles and, distances and public transportation in that area being what they are (he did not drive), his coming to Pasadena was quite a heroic venture. Not many people would have undertaken it for the sake of playing a few sonatas. Characteristic of his catholic tastes is that although he came specifically to play Beethoven sonatas, he brought as a present a recording of Yma Sumac singing Peruvian songs.

Another occasion I recall is one of the quadrennial St. Andrews Colloquia of the Edinburgh Mathematical Society which are leisurely, including social events and a concert. Kornél gave one of the principal lecture courses, was many an evening life and soul of the party, and of course took active part in the concert. I well remember his romantic rendering of Bach's Chromatic Fantasia and Fugue.

I last met Kornél some years ago in Edinburgh. Knowing that he was going to lecture to the Institute of Mathematics and its Applications, I wrote to him well ahead of time suggesting that we meet. A postal strike intervened, and I received no reply. Months later, on a Sunday afternoon he rang me: "I am in Edinburgh. Could we meet?" I suggested Monday morning but that did not suit him. "Could we not meet tonight?" I explained that I was committed to go to a talk by a town planner on his recent visit to Detroit. "Could I not come along?" We ended up by my calling for him at his hotel and bringing him home, where I had prepared a light supper to be finished in good time for us to have a little time between supper and the meeting. Towards the end of the meal Kornél looks at his watch and says, "There may be just enough time to play a sonata". So instead of having a little rest we played a Mozart sonata and then dashed off to the meeting. After the talk Kornél virtually monopolised discussion time, narrating his own experiences in Detroit some twenty years earlier and comparing the social climate then with the one described by the lecturer. He was then in his mid-seventies, had travelled from Dublin to Edinburgh on the morning, been entertained for luncheon, spent the evening with me, and seemed none the worse for all this. Next day he gave one of his stimulating lectures.

He seemed indestructible. It is a sad thought, and hard to believe, that he is no more.

CORNELIUS LÁNCZOS

B. GELLAI
Hungarian Academy of Sciences

Cornelius Lánczos was born on 2nd February, 1893 in Székesfehérvár, Hungary.

From 1911 until his graduation in 1916 Lanczos attended the University of Budapest. His professor in physics was Loránd Eötvös. The outstanding physical experimental work and interpretations of Eötvös were, in Lánczos' opinion, extremely impressive. In the Mathematics Department of the University he was a student of Lipot Fejér, the genial young professor of mathematics. After his graduation, he spent four years as an assistant of Károly Tangl at the Polytechnical University of Budapest. These four years represented the only period of Lánczos'

life when he dealt with experimental physics. In 1921 he obtained his Ph.D. degree for a thesis entitled "Function Theoretical Relations of Maxwell's Vacuum Equations" at the University of Szeged. The Professor of theoretical physics at this University was at this time Rudolf Ortvay (a former student of Sommerfeld). He himself was not a very productive researcher but he had great merits in introducing the ideas of modern physics in Hungary. He created a very stimulating atmosphere for physical research, encouraging and supporting talented young researchers. Nowadays it is less known that many of the most famous Hungarian physicists began their career under the auspices of Ortvay. Lánczos maintained a close contact with Ortvay even after leaving Hungary until the Second World War.

In 1921, due to the adverse political situation, Lánczos felt compelled to leave Hungary for Germany spending the next three years at the University of Freiburg in Breisgau, and moving from there to Frankfurt am Main in 1924. At the University of Frankfurt he became a lecturer to Professor E. Madelung. In 1926 he published in a paper an interpretation of quantum mechanics on a continuum basis in terms of integral equations. This paper preceded Schrödinger's first communication by about four weeks and therefore, strictly speaking, the earliest continuum–theoretic formalism of quantum mechanics.

He was interested in the Einsteinian equation of gravity and got in correspondence with Einstein who invited him to be his collaborator in mathematics. So Lánczos worked with him on the theory of relativity at the University of Berlin during the academic year 1928–29. This year was the most determinative one in his life. The year 1931 saw the publication of his first paper on the quadratic action principle in relativity, a subject in which he maintained a close interest. He kept in touch with Einstein throughout the following years.

It was the same year, 1931, that he moved to the United States. The following years stimulated Lánczos to undertake research in numerical analysis. For the next 15 years he was on the staff at Purdue University, Lafayette, Indiana, where, in 1938 he developed his well-known theory of economization of polynomials now known as the Lánczos Tau-method. It is highly significant that virtually all of his numerical methods were such that they were later to be found to be very suitable for forming the basis of certain significant digital computational methods. In 1942 two papers were published in conjunction with G. C. Danielson on practical techniques of Fourier analysis. Although the mathematical method, worked out by Lánczos in these papers, was oriented toward simplified hand calculation of the coefficients of a real Fourier series, later, in 1966, P. Rudnick reported the use of the method on a digital computer. The method anticipated the Fast-Fourier Transform. In the year 1943–1944, in addition to his other work, Professor Lánczos was on the staff of the National Bureau of Standards working on the Mathematical Tables Project.

In 1946 he left Purdue and from that time he held important appointments in industry. First he accepted an appointment with the Boeing Airplane Company in Seattle. Professor Lánczos regarded his years with this organization as being most fruitful ones for him. He developed his exceptional ability by which he could translate the problems of engineers into the language of Mathematics and conversely, reformulate the mathematical results in terms of engineering. In 1947 he lectured at the University of Washington, Seattle and gave a series of lectures on "The Fourier Series and its Applications". Between 1949 and 1952 he was at the National Bureau of Standards Institute for Numerical Analysis at the University of California, Los Angeles. Shortly after moving to Los Angeles his first standard work entitled "Variational Principles of Mechanics" was published; this has been re-issued many times since. A significant post that he held was being the specialist in computing with North American Aviation in 1953–1954.

In 1954 at the invitation of Dr. Eamon de Valera, who was at that time Prime Minister of the Republic of Ireland, Cornelius Lánczos accepted the post of Senior Professor in the School of Theoretical Physics of the Dublin Institute for Advanced Studies. The stimulating daily "tea-time" discussions with not only the senior but also the junior staff of the Institute for Advanced Studies contributed to the scientific results which saw a lot of publications during the "Dublin period" in many scientific papers and six standard works written in a very personal style. These standard works are: Applied Analysis, 1956; Linear Differential Operators, 1961; Albert Einstein and the Cosmic World Order, 1965; Discourse on Fourier Series, 1966; Numbers without End, 1968 and Space through the Ages, 1970. His latest book, Einstein Decade: 1905–1915 was published in 1974 in which he not only characterized Einstein but gave a summary and

explanation of each of Einstein's outstanding works that appeared in Germany and could be thoroughly understood only by Lánczos who was familiar not only with the subject but also with the German language. He remarked that he hoped to be remembered for introducing a new type of mathematical textbook. The number of his scientific papers is about one hundred.

Lánczos was in touch with many scientific institutes and universities, among others he maintained, for many years, extremely close and cordial associations with members of staff of the Department of Mathematics, University of Manchester Institute of Science and Technology. His association with this latter Institute culminated in a visit, in 1972, during which a number of projects of exceptional interest were recorded on audio- or on videotape.

Apart from his mathematical thinking being characterized by a very personal simplicity, he was a born educator. He loved to lecture and travelled extensively to do so. On the occasion he was being interviewed for a Hungarian television programme, he remarked that he was known among mathematicians, somewhat jokingly, not as a mathematician but a "mathemagician".

The American Mathematical Society awarded the Chauvenet Prize to him in 1960 for a paper on the decomposition of an arbitrary rectangular matrix into three factors, the first and third being orthogonal, the other being diagonal. The computational method is now known in digital computing mathematics as "Singular Value Decomposition of Matrices", by means of which one method of calculation of pseudo-inverse of matrices is possible, based on the Lánczos' matrix decomposition idea.

Beside numerical problems the main field of his interest was to remain what he called his "first love": the theory of relativity. An excellent paper entitled "Vector Potential and Riemannian Space" developing the relativity theory was published in the journal "Foundations of Physics" in 1974.

His whole life was accompanied by many recognitions although the recognition was never sought. The following are among the many honours he received: Membership of the Royal Irish Academy, 1957; the award of the honorary D.Sc. by Trinity College, Dublin in 1962; the honorary degree of D.Sc. by the National University of Ireland in 1970; the honorary degree of Dr. Nat. Phil. from the Johann Wolfgang Goethe University, Frankfurt, in 1972; the honorary degree of D.Sc. from the University of Lancaster in 1972.

He was a Fellow of the American Association for the Advancement of Science, and of the American Physical Society; he was a member of the American Mathematical Society, and of the Mathematical Association of America as well as the Society for Industrial and Applied Mathematics. He was a member of Sigma Xi and an honorary member of Sigma Pi Sigma. He was an honorary member of the Eötvös Loránd Physical Society, Budapest, Hungary.

In September 1972 he was invited to a Symposium on the Development of the Physicist's Conception of Nature sponsored by the European Physical Society in Trieste, in Italy. At this Symposium a very exciting event occured that was also of interest with regard to the history of science. The speaker was Prof. B. L. van der Waerden who was unaware that Lánczos was in the audience. Van der Waerden had based his talk on a letter dated 12th April 1926 from Pauli to Jordan (who was also present in the audience). In the letter a paragraph underestimated the quantum mechanics paper of Cornelius Lánczos we mentioned above. After reading out the letter, Professor van der Waerden pointed out that this had been a serious lapse of judgement of Pauli since the paper correctly formulated the eigenvalue problem in terms of integral, rather than differential operators and in fact it also came close to discovering the delta function. At this moment Lánczos was urged forward to the dais by the chairman Professor Rosenfeld and van der Waerden was heard to gasp "Are you Lánczos?" It was a most moving scene and many photographs were taken of Lánczos shaking hands with van der Waerden.

In addition to an exceptional gentleness, Lánczos' extreme modesty was almost legendary. It is perhaps appropriate to use the words he himself used in that part of his article "Why Mathematics?" related to Nobel Prize winners of the twenties: "How much modesty was at home, how little boasting of his own importance"; the quotation can be continued to fit our own days where unfortunately emphasis is on "the wonderful things that *I* have accomplished".

During the last years of his life, with the latin phrase "cursum consummavi" in mind, his contact with Hungarian scientists was renewed. A sincere friendship developed between Lánczos and the outstanding theoretical physicist professor Géza Györgyi. In 1973, as a guest of the Eötvös Loránd Physical Society, Professor Lánczos spent one month in Hungary where he

participated in two scientific meetings: The Scientific Meeting of Physicists organized by the Eötvös Loránd Physical Society, in Szeged, followed by a Numerical Colloquium organized by the Bolyai János Mathematical Society, in Keszthely. It is of interest to mention that this was the first time that Lánczos had visited Szeged, as when he obtained his Ph.D. degree in 1921, the University of Szeged was in fact in Budapest.

On 16th June 1974 he arrived in Hungary to pay a visit to the Eötvös Lárand University and the University of Szeged.

In the last days of his life besides the many official visits in Budapest he had been working on the topic "Fourier Analysis of Random Sequences", the topic he was due to lecture on at the Numerical Colloquium in Dublin, in July 1974. He was of completely sound mind up to and including the day of his death. There was only one thing he was worried about on the day he died, he remarked, "I feel that I should be working harder".

In the evening of 24th June 1974, in Budapest, he went to discuss the topic of a future TV interview when he became unwell and he died of heart attack the same night. His funeral took place in Budapest on 5th July 1974.

It is apposite to declare, as did one of his friends that Lánczos' passing would leave a gap impossible to fill, representing a loss not only to Mathematics but to science in general.

Perhaps the most fitting conclusion would be to use again Lánczos' own words form his article "Why Mathematics?", which can serve as a guiding principle in our scientific research: "We will go on pondering and meditating, the great mysteries still ahead of us, we will err and stumble on the way, and if we win a little victory, we will be jubilant and thankful, without claiming, however, that we have done something that can eliminate the contributions of all the millenia before us".

Acknowledgement—To the writing of this biography valuable assistance most kindly given by Mrs. Halász (née Lánczos) is gratefully acknowledged.

CORNELIUS LÁNCZOS IN DUBLIN (1953–1974)

J. R. McConnell
Institute for Advanced Studies Dublin, Ireland

The name of Cornelius Lánczos first became known to most Irish mathematicians and physicists during 1942. In the autumn of that year the late Professor Schrödinger began in the Dublin Institute for Advanced Studies a sequence of seminars on general relativity, which had been inspired by his reading the Lánczos paper "Matter Waves and Electricity (*Phys. Rev.* **81**, 713–720 (1942)). Some ten years later influenced by his apprehension of the possibility of a nuclear war in the United States, Lánczos came for a year as a visiting professor to the Institute. During the year the Governing Board of the School of Theoretical Physics recommended to the Irish government that he be appointed permanently as a senior professor. This was done and Lánczos accepted the appointment. Thus began the most productive period of his academic career which continued without flagging until his death.

Lánczos soon became very much a part of Dublin society and cultural life. His accomplishments as a musician, his interest in the theatre and the arts and above all his sympathy for people and their problems—intellectual, personal and social—quickly added to the distinction that he had already earned as a scientist. Of the many who expressed deep regret and shock at his sudden demise, I recall in particular the nun who was a member of a society of teachers to which Lánczos had lectured on mathematics in his clear and captivating style, the teenage assistant in a photographic studio who had frequently prepared slides for his lectures, and the middle-aged housewife who had met him at receptions and to whom Lánczos without affectation had attentively listened while she expressed her views. Though his interest in scientific investigations was intense and his efforts to pursue research were tireless, he willingly gave his time to those who needed encouragement, guidance or just a hearing.

In Cornelius Lánczos were blended together the natural and the supernatural, the science and the humanities. A devout believer he attended regularly at the synagogue, where he ministered as a levite. At the same time he had a keen appreciation of natural goodness and of beauty in thought and form. He led a very full life. Indeed he enjoyed living so much that he felt that one's living was worthwhile, even if there were no hereafter. While he reverenced his own race, he was all things to all men. He would not scruple to omit attending the synagogue on the sabbath if he had to assist somebody in immediate need. He continually gave away a great deal of his money; in fact his charity was so well-known that he became the target of both the deserving and the undeserving. He had a high regard for the Cistercian monks from whom he received most of his pre-university education and in 1971 he loyally travelled to Hungary for the diamond jubilee of the graduation of his class. He encouraged young musicians by inviting them to come together in his home. He supported theatrical enterprises both by his presence and financially. His distinguished appearance made him a favourite subject for painters, sculptors and photographers.

Dublin has lost in Cornelius Lánczos something more than a brilliant mathematician; it has lost a friend. Public tributes were quickly paid to his memory. Irish television produced a lengthy feature on him. The Royal Irish Academy held a special session to commemorate its distinguished member at the end of its 1974 Conference on Numerical Analysis, which Lánczos was to have addressed. This session was attended by many mathematicians from abroad and also by distinguished Irish public figures including ex-President de Valera. By all he is remembered as a lovable person.

LÁNCZOS AND THE INSTITUTE FOR ADVANCED STUDIES IN THE EARLY SIXTIES

EDUARDO L. ORTIZ
Imperial College University of London, England

The Institute for Advanced Studies was created as a result of an initiative by Mr. Eamonn de Valéra, who as Taoiseach (Prime Minister) submitted such project to the Dáil Éireann (the Irish Parliament) on July 6, 1939. The considerations of his proposal clearly reflect a concern with the revival of the Irish culture.

The main objective of the new Institute was the promotion of research activities in two quite different fields: Celtic studies and Mathematical Physics. The School of Celtic Studies had the task of providing an adequate environment for a body of experts to undertake the analysis and publication of a large mass of early modern Irish manuscripts. This would in time contribute to restore to the Irish an important side of their cultural heritage and to make of Dublin a unique centre for studies on the Celtic history and literature.

The School of Theoretical Physics was proposed with an equally valid argument: the revival of a brilliant Irish tradition, perhaps best represented by the names of Stokes, Kelvin, Boole, Hamilton, FitzGerald and Larmor, in a "branch of science in which you want no elaborate equipment, in which all you want is an adequate library, the brains and the men, and just paper".

Exceptional circumstances concurred to make this last idea a success: the determination and highly influential position of the proposer, the advice he sought in scientists of the stature of Conway, Birkhoff and Whittaker, and—perhaps equally important—the fact that many central European scholars were at the time shocked by the advances of Hitler's policies. As a result of which a number of prominent scientists, then mainly from Austria and Germany, were seeking positions in other countries.

In 1938 Mr. de Valéra was in Geneva in his capacity of President of the Meeting of the League of Nations and made efforts through the Irish diplomatic service to meet Professor Erwin Schrödinger. The meeting was to have considerable influence in the development of the exact sciences in Ireland.

By October 1939 Schrödinger was in Dublin and a few months later, in June 1940, the Act which created the Institute for Advanced Studies was signed by the President of the Republic. In November the Governing Board met for the first time and designated Schrödinger Director of the

new School of Theoretical Physics. Another foreign member of the School who joined at that time was Dr. W. H. Heitler, who had left Göttingen for Bristol in 1933.

The Institute occupied two adjacent houses in Merrion Square, one of the most beautiful of the remaining Georgian squares, nearly opposite Oscar Wilde's home. On another side of the square stands the National Gallery of Ireland, generously endowed by George Bernard Shaw.

Also close to Merrion Square are the campus of Trinity College (with its well known Library) and the National Library of Ireland. James Joyce tells us in one of his stories on Dublin's life of the discussions on art, politics and literature generations of students held on the steps of this Library. One of the students portrayed by Joyce is Felix Hackett, the Irish physicist and engineer, who later was a founder member of the Governing Board of our School and as such participated in the designation of Schrödinger. Some years later, as Chairman of the same Board, he appointed Lánczos Senior Professor of the Institute.

Lánczos joined the Institute for Advanced Studies in 1952–1953 as a Visiting Professor at a time when Schrödinger was acting Director. In that year, as in many others, the activity of the School was considerable: the visitors included Lichnerowicz, Prager, Coleman and Coxter. A colloquim organized by Dirac, Schrödinger and Synge was attended by more than 50 participants.

Lánczos gave several lectures during that period and all of them centered on topics of numerical mathematics. His lectures included such interesting topics as the high precision approximation of the Gamma function, the numerical differentiation of Fourier series and problems in interpolation and smoothing. The chapter on Numerical Quadrature in *Applied Analysis* grew out of a series of problems proposed by Schrödinger at that time.

He went back to America after this one year visit to take up an appointment with North American Aviation Co., Los Angeles, where he stayed until 1954.

Before his first visit to Ireland, Lánczos had resigned his post at the Institute for Numerical Analysis, University of California, Los Angeles, where he undoubtedly helped that institution to achieve the position of prominence it had at the time. His withdrawal from California followed a change in the political climate of the United States which reached its climax with the McCarthy investigations.

In 1954 Mr. de Valéra offered Lánczos a permanent position in the Institute for Advanced Studies as a Senior Professor, possibly the highest scientific position in the Irish establishment at the time. Lánczos made his home in Ireland for the rest of his life.

It was during this Irish period that he wrote all but one of his books.

In 1961 the staff of the School of Theoretical Physics included Lánczos and Synge as Senior Professors (Schrödinger died in Vienna that year), three young Professors and three Scholars. The Scholars were usually required to hold a doctorate before being admitted. Besides its own staff, the Institute was the meeting place for a number of talented mathematicians and theoretical physicists from Trinity and University College Dublin.

Facilities at Teach Hamilton (Hamilton House), as the buildings occupied by our School were called, were excellent: quiet rooms in a delightful square and an up to date Library ably runned by a former Scholar, Miss E. Wills, who also took care of the administrative aspects of the School, then under the command of Professor Synge.

We used to congregate for tea every morning at around eleven. Tea was served in the Library on a large table flanked by a blackboard on one side and two rows of book-cases on the other. There were no formal lectures at the Institute and tea was the occasion for spontaneous and stimulating discussion which would involve all of us, and also for more personal exchanges in smaller groups. Our tea was frequently attended by colleagues from the Universities or visitors from abroad, who stayed with us for short periods.

At those meetings there were memorable discussions between Professors Synge and Lánczos on the most varied subjects. Synge had a gift to engage Lánczos in a discussion even when the latter did not want to participate. If all failed, a casual remark on some aspect of Einstein's work or life would involve the indifferent Lánczos vehemently in the conversation. We knew then that the most ingenious, sharp and witty arguments would follow for quite a while.

Lánczos was irresistibly attached to dictionaries and encyclopedias and would occasionally disappear in the middle of a discussion to look for the precise meaning of a word or to check a fact or a date. But more than once he could not resist the temptation of going on to the next reference (or word!) and it was the duty of one of the Scholars to go to the back of the Library

and rescue him, if not for the discussion, at least for the benefit of Mrs. Lánczos, who otherwise would not have had him for lunch...

It was a unique experience to hear Lánczos talk about the Germany of the twenties and his remarks on the changing attitudes of scientists in his long span of scientific life. He had a well known friendship with Albert Einstein, who invited Lánczos to collaborate with him in Berlin in 1928. This friendship, which lasted till Einstein's death, was carried over to America and is documented by a long correspondence between the two men which is treasured by the School of Theoretical Physics, where it is deposited.

Lánczos was critical of trends in Mathematics and Physics which in his view only meant turning the handle without contributing any new ideas. He occasionally expressed the view that it would have been more difficult for an Einstein to emerge in the scientific millieu of our days than it was at the beginning of this century. He was open and curious about new ideas and developments in his many fields of interest. When I became his student at the Institute, my main training was in pure Mathematics and I still remember with affection his curiosity to know how and why Schwartz' distributions or Sobolev's spaces threw some light on problems that had puzzled him when attacking them with a more classical machinery.

Now that we can look at Lánczos' life with a little more perspective, we realize how much his scientific career was a constant involvement with some of the most original ideas of our times, like relativity, quantum theory and computers' Mathematics.

Lánczos lived with his wife, Ilse Hildebrand, a highly educated German lady with a remarkable gift for the history of ancient art, in the ground floor flat of a Georgian house situated in a street right behind the buildings of our School and had the unique privilege of being allowed to go home across the back garden of Teach Hamilton. His flat had a large living room with an impressive grand piano. Lánczos had a fine musical taste and loved to play when visiting some of us who had a piano at home.

As much as his beloved teacher Albert Einstein, Lánczos looked very much like an artist. Once, while queuing for a bus he was engaged in conversation with a young student who at a certain point asked him—quite rightly—whether he was a musician or a mathematician. Lánczos replied with his strong Hungarian accent, "Both, young man, both!".

I would venture to say that tea in Ireland is even more important than it is in England nowadays. If talking over a cup of tea was so stimulating in the mornings, no less so were our occasional visits in the afternoon to nearby Grafton Street for a cup of tea and pastries in one of the traditional large stores. Walking along Grafton Street Lánczos would inevitably meet some among his unique range of friends and acquaintances. They might include the President of Eire, who would stop for a word with him or maybe a fellow member of the Academy, somebody from the Dublin Jewish community or perhaps a catholic or protestant priest. Equally well a fervent critic of all denominations. Students from the Universities, artists or occasional eccentric Dublin old lady riding a bicycle with a flowery hat should not be excluded from this list.

Lánczos was at times reminiscent of the integrated life of European University cities before the Second World War and perhaps Dublin had that quality about it too. Although he never again settled permanently in the United States, that country remained very close to his heart and often he referred to it as "my dream land". Apparently he enjoyed as much his long association with Universities as his contacts with industry, which he rated very highly for the motivation they provided in his work on numerical Mathematics.

We also had at the Institute a weekly Seminar on Wednesday afternoons which was regularly attended by most of the mathematicians and theoretical physicists working in Dublin or nearby. The list of speakers included some of the most remarkable contemporary scientists.

Most people outside Ireland may not know that Mr. de Valéra was trained in his younger years as a teacher in Mathematics and that he maintained throughout his life a keen interest in the subject. The President of Eire would some times attend our Seminars and there were Scholars who maintained that through his long life at Parliament he had wisely learnt to sleep while others debated. We naturally were anxious to know whether he practised this remarkable ability while visiting us, but I must report in all fairness that we collected no evidence pointing in that direction.

Lánczos kept an active interest both in Mathematics and in world problems till the very end of his life. I saw him, frail and lively, a few weeks before his death during a visit I made to Dublin to

participate in Professor John Miller's Seminar at Trinity. He insisted on coming to my talk, which referred to some of his early work and, as usual, made the most penetrating remarks. We had dinner together with Mrs. Lánczos at his home. Mrs. Lánczos tried to persuade him not to engage himself in a lecturing tour in the West coast of Canada and the States, but he had a strong desire to see there his son Elmar and his grandson.

He was deeply concerned with the problems of the Middle East and we were engaged in a conversation on this subject when two of his friends, a young lady and a priest, came to fetch him for a weekly meeting where papers on Philosophy were read and discussed.

REMINISCENCES OF A CHERISHED FRIEND

I. RHODES
National Bureau of Standards, Washington, D.C., U.S.A.

What his admirers found, probably, most appealing in Cornelius Lánczos was his self-effacement. In the early 1940's our New York Mathematical Tables Project experienced great difficulties in attracting mathematicians to supervise its horde of manual computers, gathered from the Welfare Rolls, because—in many minds—a WPA Agency was associated with "Boondoggling". During that tragic period of stress and discouragement, a gracious letter from one of the world's foremost scientists spread the Balm of Gilead over our bruised souls. Not only did Professor Lánczos (then at Purdue) lavish ample praise on our Tables, but subsequently deigned to Accept Dr. Arnold N. Lowan's invitation to join our staff as Consultant for 1943.

If one failed to catch a glimpse of his ascetic, high-browed face with its deep-set lustrous eyes, one would have no way of distinguishing that mental giant from his neighbors, the majority of whom had been immensely surprised to learn that a number is burdened with a feature, called sign. Lánczos never evinced the slightest condescension toward any of our humble $57 month workers. To the contrary, he cheerfully shared their tables at the cafeteria, and often took a lively part in their holiday picnics. His marvelously illuminating, patient, and painstaking instruction of these mathematical illiterates bordered on the sublime. Somehow, he also found the time to carry out a prodigious amount of scholarly tasks for the Project. Six years later, he came for a more protracted stay at the Los Angeles branch of our National Bureau of Standards Computation Laboratory. Like Gauss, whom he idolized, Lánczos was a peerless computer.

In marked contrast to the touching sympathy, he displayed toward the unskilled laborers, he could be quite intolerant of any learned member of our society, who exhibited —what he regarded as—unwarranted vainglory. At the colloquia, which we attended together, I no longer ventured to voice appreciation of certain presentations, after having expressed enthusiasm over an earlier paper. My companion had given me a 'there she goes again' look and exploded: "Whom have you just heard—a Gauss, a Cauchy, an Euler?! You must learn to be more discriminating in your evaluation of a mathematical offering!" On the other hand, he was generous with his praise for colleagues whom he considered worthy of approbation. When I expressed admiration for the non-Jewish scholars, who voluntarily left Germany in protest over the Nazi regime, he told me: "Think over, instead, the noble action of (a man, whose name I regret to have forgotten) who, when offered a lucrative Professorship in the United States, refrained from accepting it, because the available position was so urgently needed by a Jewish scholar threatened with the impending holocaust."

Regarding his own exile, Lánczos showed a surprising lack of rancor. He felt fortunate to find himself in one of the 'world's only two remaining corners of freedom'—as he put it at that time—(the other being Ireland). It is highly ironic that this particular 'corner' later declared him—for a while—persona non grata, because he gave refuge to another exile, whose frank opinions displeased Sen. Joe McCarthy. This verdict, too, Lánczos accepted in the spirit of Ecclesiastes, being no longer surprised at the bigotry and moronity, rampant on our wacky planet. He found a welcome haven among his gentle Irish neighbors, and derived much solace from his piano, as did his revered Mentor and Friend, from the violin.

The numerous books and articles which Lánczos had written on Einstein testify to his deep veneration for the Master. However, I was not prepared for the blaze of anger, with which my friend greeted an innocuous remark of mine. I had relayed to him a—probably imperfect—recollection of Einstein's statement, to the effect that he was amazed at the tremendous kudus, being bestowed upon himself, while insufficient homage was being paid to his great fellow-scientist, Max Planck. "Don't ever repeat such an absurd story!", thundered Lánczos, "Einstein was a thoroughly honest and truthful man. He was quite well aware of his own vast superiority over Planck, and would not demean himself by uttering such a palpable falsehood".

Lánczos' reference to an interesting incident involving van der Waerden is contained in his acknowledgement of congratulations, sent by the extant members of the Mathematical Tables Project, in which we anticipated that a glorious celebration would be tendered him on his 80th birthday. The first paragraph of his letter reads

> Of course, I was very touched by the cable which came from the old gang of the MTP, still going strong in Washington. How wonderful! The 'celebration' was not so terribly 'glorious', since I cannot quite see what is so exceptional, if somebody has the good luck of reaching his 80th birthday. I am certainly grateful for a lucky fate which granted me this advanced age, but why should the *day* of finishing his 80th year (or is it only 79?) be so terribly important? At all events: the Irish Academy will celebrate me at a special meeting, at which van der Waerden, the historian, will be the speaker (who namely 'discovered' me at the Trieste meeting—celebrating the 70th birthday of Dirac—as the precursor of Schrödinger), and the 'Festschrift' will be handed over allegedly on 30th April.

In his youth, Lánczos was obsessed by a burning desire to explain away the seemingly dual nature of light. A score of years later, we wasted precious time on me, in trying to expound that early theory. As far as I can make it out, he conceived the surface of the universe to consist of the juxtaposition of tightly squeezed together crests of Fourier waves with infinitesimal grooves between them. I cannot recall now, how this accordion structure accounted for the two aspects in which light is being regarded, but I vividly remember his amusement at the reaction that his exposition had elicited from a young colleague in Frankfurt—now a world-renowed scientist. The latter's considered opinion had been: "Sounds crazy to me Niels, but—after all—what guarantee do we have that God is sane?"

In his entire long life, Cornelius Lánczos never doubted the absolute lucidity of the Great Geometer. Indeed, he was quite convinced that the Creator of the Universe would not commit 'the terrible error' of allowing a Pythagorian equation of four dimensions to deviate from its logical form of a positive definite metric. He died a contented man, believing that he had succeeded in reversing the sign of t^2 in that formula. I am not competent to judge the validity of his last two papers in 'Foundations of Physics', but I fervently hope that posterity will rule in his favor.

To the few surviving, erstwhile entirely assimilated, German Jews, Hitler's reign of terror restored the consciousness of their identity. Cornelius Lánczos, the Levite, who had been twice married to Christians, began to take immense pride in his heritage. He raised his son in the faith of his fathers, and Yehoshua Lánczos is frequently called upon to perform his priestly rites at the altar of a Seattle synagogue. Cornelius' widow, Ilse, now residing in Munich, is an avid student of Judaic lore and has made excellent progress in mastering the Hebrew language. Perhaps it was providential that her husband did not live to read the ominous words, uttered by a high military officer in our country, for which Lánczos ever harbored the warmest affection, and which he was delighted to revisit, on his frequent lecture tours.

His letter to me of March 20, 1974, ends in the first verse of the Hebrew Mourner's Dirge, which he had quoted in connection with his last book on Einstein. Dolefully, I am now intoning it in the honored memory of his illustrious disciple, Cornelius Lánczos:

YISGADAL V'YISKADASH SHMEH RABBO!